Space Weather Technical Forecast

Issued on Sunday, 25 December 2022 at 01:28 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Potential Earth-directed CMEs on 26 and 27 December with possible G1/Minor Storms and low risk of G2.

Analysis of Space Weather Activity over past 24 hours
Solar Activity: Solar activity has been Low over the last 24 hours with only limited C-class flares observed. The largest region is AR3169 (Fsi/Beta), which has spread slightly over the last 24 hours but continues to be a bipolar region with little magnetic complexity. AR3171 (Cao/Beta) neighbours AR3169 and despite being simple, this region has reversed polarity to the expected order of magnetic orientation of northern hemisphere regions. The remaining regions are magnetically simple, but AR3172 (Cao/Beta) has developed a trailer region.

A CME which left the northeast quadrant of the Sun around 24/0230UTC has been analysed, with this feature potentially glancing the Earth on 26 December with low confidence. Three possible CMEs were observed emanating from the vicinity of AR3169 at intervals throughout the 24 hour period and will be analysed should sufficient imagery become available. A filament lift off from the northern crown around 24/1100UTC may have produced a CME but current imagery is inconclusive.

Solar Wind / Geomagnetic Activity: Solar wind speeds started the period averaging between 600-700km/s in the presence of a high speed stream from coronal hole 56, with this influence waning through the 24 hours, reaching around 500km/s by the end of the period. Density has also steadily decreased from above average to average or below average levels. Total magnetic field strength weakened from moderate levels at 10nT to weak levels through the 24 hours. The north-south component, Bz, also varied weakly with no significant polarity bias. Phi angle has been predominantly positive (away from the Sun). Geomagnetic activity started with a G1/Minor Storm period between 24/0300-0600UTC becoming Unsettled to Active through the remainder of the period.

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10MeV) as measured at GOES16 remained at Background levels.

High energy electron flux (greater than 2 MeV), as observed by GOES16, started at background levels to rose to reach high (1e3 pfu) levels by 24/1405UTC and has oscillated between high and moderate levels close to the high threshold since that time. Electron fluence initially increased quickly, but has since shown indications of levelling off, reaching 4.18e7 integrated pfu by 24/2359UTC.

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Met Office Space Weather Technical Forecast

Four-Day Space Weather Forecast Summary
Solar Activity: Solar activity is expected to be mainly at Low levels, with a slight chance of M-class flaring.

Solar Wind / Geomagnetic Activity: A CME which left the Sun on 21 December is likely to have passed the Earth with no effects and has been removed from the forecast. Two further CMEs have forecast to have Earth-directed CME. The first, which left the northeast quadrant of the Sun 24/0230UTC may glance the Earth on 26 December. A further CME which left the Sun 23/2330UTC may arrive at earth on 27 December based on recent Enlil forecasts.

The coronal hole high speed stream from coronal hole 56 is expected to continue to wane through 25 December. A further high speed stream may then connect either late on 26 or during 27 December, but with low confidence, as the feature continues to weaken. Any further coronal hole connections may however be masked by CME arrivals.

Geomagnetic activity is forecast to be mainly Quiet to Unsettled on 25 December. There is then a risk of Active or G1/Minor Storm intervals on 26 and 27 December due to possible CME arrivals and a chance of these combining with the high speed stream connection. Any CME arrival on 27 December could see residual storming into 28 December.

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux is expected to remain at Background levels throughout.

High energy electron flux (greater than 2MeV) may continue at moderate to high levels through the next four days due to high speed stream inputs, but these high speed streams could also distort the radiation belts out of their natural orbits. CME arrivals could have the effect of also distorting belts and potential redistributing electrons away from GEO orbits. Confidence is therefore low for the possible behaviour of electron flux over the next four days.
Electron fluence values are likely to initially follow a slightly rising trend through 25 December, with the subsequent trend dependent on a low confidence high speed stream connection and potential CME arrivals. There is a low but increasing risk of reaching the Active threshold by the end of the forecast period.

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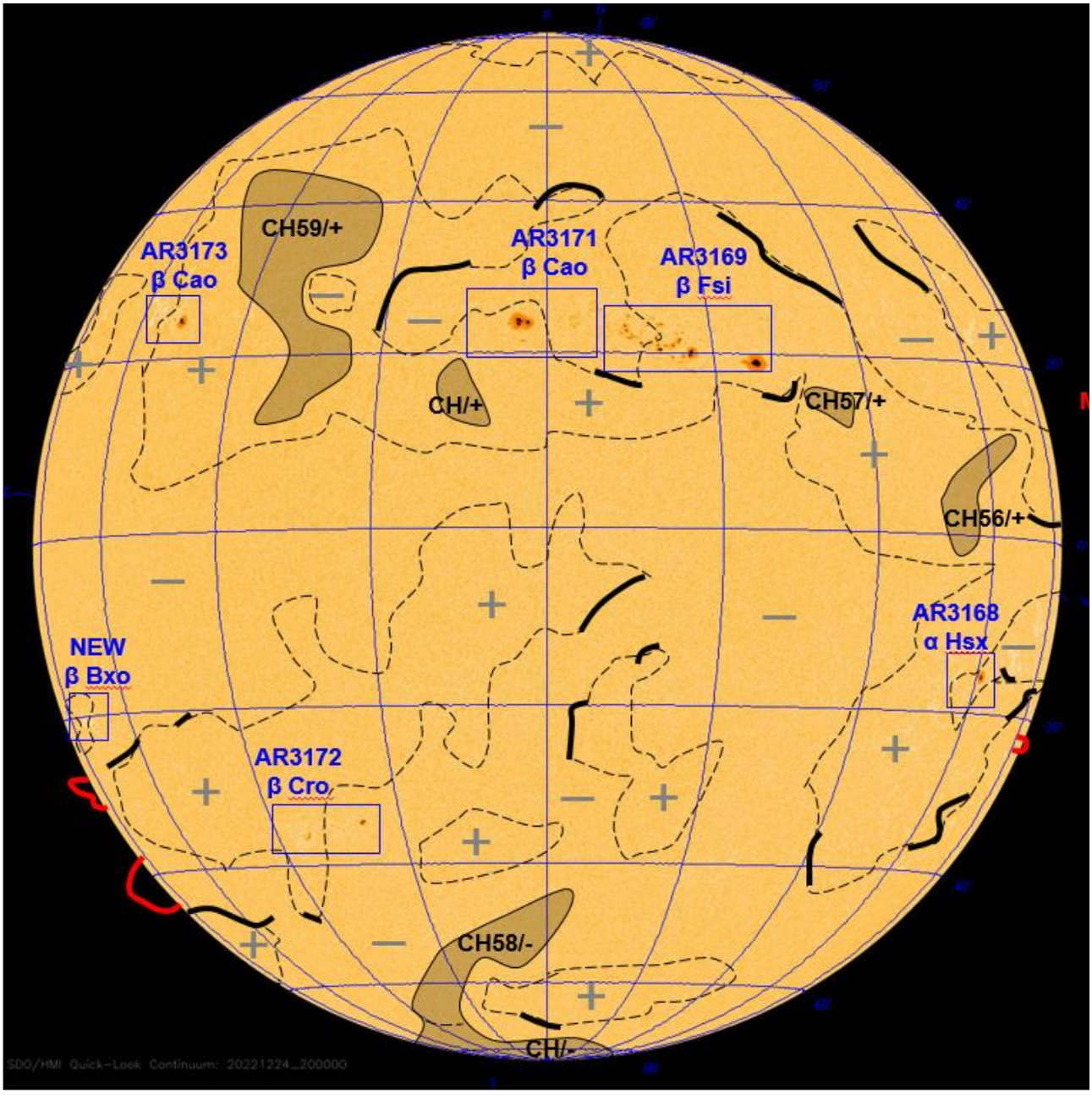
Figure 1. Solar Analysis Valid 24/2000UTC.



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Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

A CME which was due on 24 December appears to have not arrived and is likely to have missed the Earth. The next CME with a potential Earth-directed component left the northeast quadrant of the Sun early on 24 December and may glance the Earth during 26 December. Main uncertainties with this CME are the size of angular size of the cone and possible speeds, with a large margin of error across the Enlil ensemble. Given the location of the eruption, in the northeast, slight changes in initial parameters could have a significant impact on whether the feature affects Earth. A further CME which left the Sun from the southwest quadrant late on 23 December may arrive at Earth on 27 December, although this is also low confidence due to limited imagery. Three eruptions occurred from the vicinity of AR3168 during 24 December and these will be analysed once sufficient imagery becomes available.

Otherwise solar wind speeds are varying between elevated and slightly elevated levels due to the apparent waning influence of coronal hole 56. Coronal hole 57 is then due to connect either late on 26 or during 27 December, but this has shrunk through the last 24 hours, with any significant impact on solar wind speeds uncertain. In both cases the solar wind speed signal could be masked by the potential CME arrivals.

Geomagnetic activity is forecast to be mainly Quiet to Unsettled on 25 December with the coronal hole high speed stream continuing to decline. The combination of CME arrival and high speed stream could lead to Active or G1 /Minor Storm intervals on 26 December, with a very slight chance of G2/Moderate Storm given the potential for a more direct arrival. Effects of the high speed stream are then likely to continue through the remainder of the period, with a risk of a further CME arrival on 27 December, but with low confidence of further G1/Minor Storms.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	Yes	5	50	20	20
Strong	G3	No	1	5	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
24/0545	Partial	Filament	NE quadrant	Around 1100km/s	26 December	May combine with CH57 HSS
24/0838	Partial	Filament	S centre	300km/s	27 December	Low confidence in arrival time

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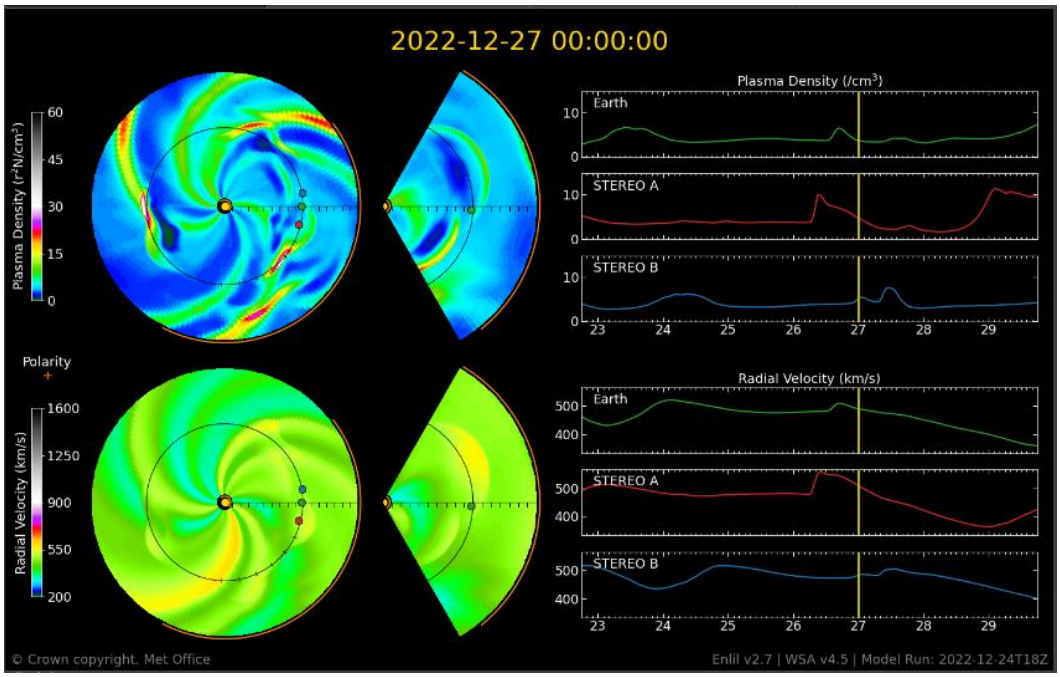
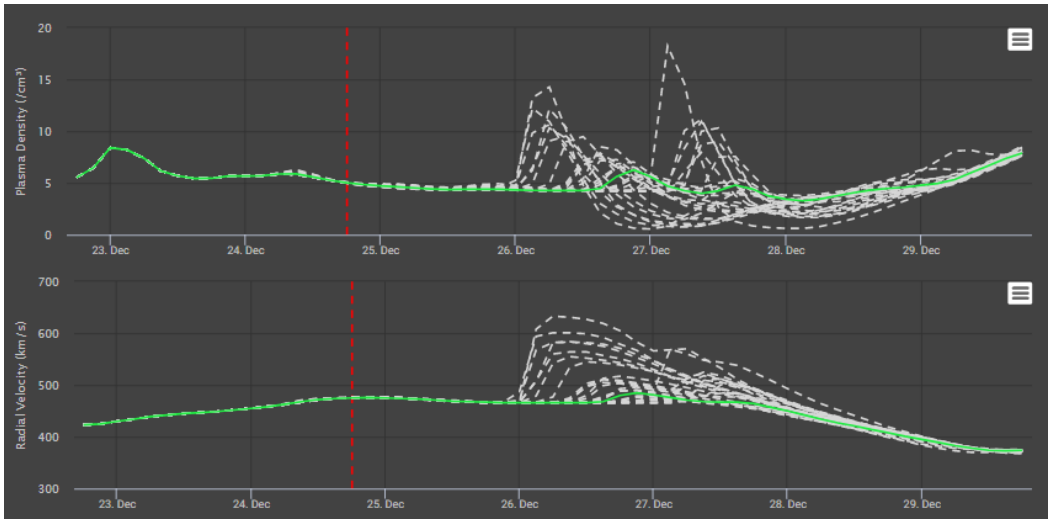
Figure 2: Enlil run showing potential CME arrivals on 26 and 27 December





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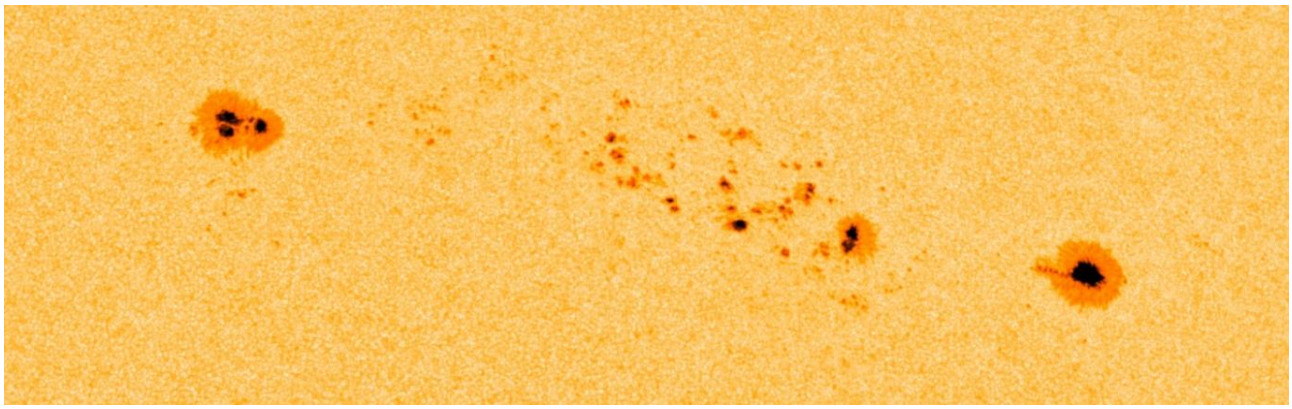
Radio Blackouts - X-Ray Flares:
Solar activity has been Low, with large, complex but magnetically simple bipolar regions on the visible disc. There have been a series of possible CMEs emanating from the vicinity of AR3169 in the northwest quadrant through the last 24 hours, which may be a precursor for further development of this region.

Activity has been below that expected of similarly complex regions, with a 25% risk of M-class flaring reflecting a generally muted recent history of the visible sunspot groups. Further regions are forecast to rotate onto the visible disc later in the period, based on analysis of far sided STEREO imagery and these will be analysed once any regions become visible.

X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	R1-R2 M Class	No	25	25	25	25
Very Active	R3 to R5 X Class	No	1	1	1	1

Figure 3: HMI-intensitygram imagery of AR3171 (left) and AR3169 (right)



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Solar Radiation Storms - (High Energy Protons):
The high energy proton flux (greater than 10 MeV) is expected to remain at Background levels. Forecast probabilities have been raised a little relative to recent guidance, due to the westward advance of developing AR3169, although there is as yet no enhancement observed at GOES16 from any flare activity from this or any other region.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1

* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)

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High Energy Electrons Event (≥ 2MeV):
High energy electron flux (greater than 2MeV) is currently varying between moderate and high (1e3pfu) levels, after a rise from background levels earlier in the last 24 hours. This increase appears to have coincided with a gradual weakening of the solar wind speeds and could be a result of radiation belts relaxing into their natural orbits.

The forecast is subject to notable uncertainty. Based purely on effects from coronal holes, a further rise in electron counts would be likely on 26 December due to the effects of coronal hole 57, but as this is weakening, effects from the high speed stream of this feature are considered unlikely. The CME forecast for 26 December would have the expected effect of compressing the radiation belts, based on the forecast speed with any increase then delayed until a relaxation as the effects of the CME wane.

The rise could however be limited based on the strength of any geomagnetic activity which could redistribute electron populations. The further possible CME on 27 December may have similar effects to the 26 December CME of compressing belts and redistributing electrons.
Electron fluence values are likely to initially follow a slightly rising trend through 25 December, with the subsequent trend dependent on a low confidence high speed stream connection and potential CME arrivals. There is a low but increasing risk of reaching the Active threshold by the end of the forecast period.

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	5	20	30	30
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

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